June 2008

Nano @ NIST: Maximizing the Benefits and Minimizing the Risks of Nanotechnology

A vast assortment of job-creating, economy-building innovations are emerging from laboratories across the globe thanks to progress in understanding and controlling matter at ever finer scales—all the way down to assemblies of a few atoms. Research and services at the National Institute of Standards and Technology (NIST) aim to ensure that this nascent nanotechnology revolution will blossom in the United States. NIST focuses on building the supporting technical capabilities that U.S. industry needs to master the exceptionally small and build a competitive advantage in the growing international markets for nanotech products.

The Center for Nanoscale Science and Technology (CNST) and NIST's nine other major laboratories are developing measurements, standards, and data crucial to industry's development of products for a nanotechnology market that could top $2.5 trillion within the next decade—or about 15 percent of global manufacturing output. Already, worldwide sales of nano-enabled products—from cancer drugs, wound dressings, and dental adhesives to computers, car parts, and cosmetics—approach $90 billion. But the best is yet to come. NIST is helping to clear technical obstacles, including uncertainties about potential environmental, health, and safety risks, with the aim of opening the way for an ever more diverse range of prospective payoffs. In 2008, more than 150 nanotechnology-related research projects were under way in the NIST laboratories. Here are a few examples of where NIST's nanotechnology research is leading:

- New measurement tools for ensuring the quality of nanoscale particles, nanotubes, and other nanomaterials that will be the building blocks of new technologies across a multitude of markets—from consumer products to construction and from health care to homeland security.
- Powerful new imaging and diagnostic tools that exploit the unusual properties of quantum dots and magnetic nanoparticles to "see" and "analyze" cancer and other diseases at the level of individual cells, enabling earlier detection and less invasive treatment with greater specificity.

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Assistant Facility Manager Russell Hajdaj prepares silicon wafers that will be "baked" as part of the processing required to produce new types of semiconductor devices for research at the NIST Center for Nanoscale Science and Technology (CNST).

Nanotechnology Is . . .

... the understanding and control of matter at dimensions of roughly 1 to 100 nanometers (billionths of a meter), where unique phenomena occur and enable novel applications. It involves imaging, measuring, modeling, and manipulating matter at this length scale. The field encompasses science, engineering, and technology—at the nanoscale.

National Nanotechnology Initiative

- Affordable flexible arrays of transistors made from "self-assembling" organic materials that can be manufactured into large plastic displays pliant enough to be folded and stowed inside your cell phone.

About NIST

A non-regulatory agency in the U.S. Department of Commerce, NIST is an essential component of our nation's technology infrastructure. It performs measurement research, provides funding support, and delivers technical services that underpin U.S. innovation and industrial competitiveness.

NIST carries out its mission through four cooperative programs:

- The 10 NIST Laboratories conduct measurement-related research and provide services U.S. industry needs to continually improve products and services.
- The Baldrige National Quality Program manages the annual Malcolm Baldrige National Quality Award, which recognizes and promotes performance excellence and quality achievement among U.S. manufacturers, service companies, educational institutions, health care providers, and nonprofit organizations.
- The Hollings Manufacturing Extension Partnership delivers technical and business assistance to smaller manufacturers through a nationwide network of local centers.
- Begun in 2008, the Technology Innovation Program provides cost-shared awards to industry, universities, and consortia for research on potentially revolutionary technologies that address critical national and societal needs.

With major facilities in Gaithersburg, Md., and Boulder, Colo., NIST has a staff about 2,800 employees—including three Nobel Prize winners—as well as 1,600 affiliated field agents. In addition, it hosts about 2,600 associates and facility users from academia, industry, and other government agencies. For fiscal year 2008, NIST's resources total $931.5 million.

- Nanowires only a few atoms across, graphene films, and other nanostructured materials that have amazing properties, such as the ability to carry electrons at incredible speeds, and that will be the basis for future generations of computers, sensors, batteries, lasers, and more.
- Data storage devices that employ precisely controlled arrays of magnetic nanoparticles to achieve capacities that will dwarf those of today's most advanced hard disk drives.
- Improved formulations of cement—perhaps the world's most widely used manufactured material—that perform better and last longer, thanks to a better understanding and control of their nanostructure. Improvements include reduced emission of greenhouse gases during production of this workhorse construction material, which currently accounts for 5 to 10 percent of global releases of carbon dioxide.

At a Glance: NIST Role

NIST's technical contributions underpin progress toward nanotechnology's many anticipated market applications and societal benefits worldwide, from cost-competitive solar power to reliable supplies of clean drinking water. Research is also aimed at leveraging advances in nanotechnology to improve NIST's own measurement capabilities and services. In addition, the NIST laboratories assist other federal agencies to exploit nanotechnology to further their missions in areas such as national security, food safety, and environmental protection.

NIST participates in the federal government's National Nanotechnology Initiative (NNI), which coordinates the individual and cooperative nanotechnology-related activities of 26 agencies with diverse research and regulatory responsibilities. NIST is one of 13 agencies that funds nanotechnology research, which, government-wide, totals almost $1.5 billion in fiscal year 2008.

Nanotechnology-related efforts are aligned with seven of the NNI's eight major categories of research and other activities. Sustained progress

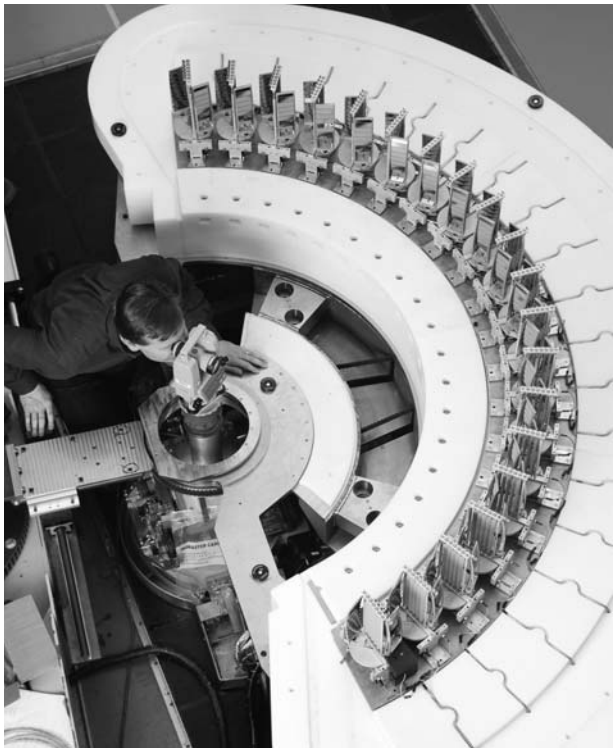
in each category is critical to realizing the NNI vision of a "future in which the ability to understand and control matter at the nanoscale leads to a revolution in technology and industry that benefits society." NIST contributes to technical advances in the following areas:

Instrumentation research, metrology, and standards—This is NIST's nanotechnology strong suit, a natural fit for an agency that serves as the nation's measurement authority and its link to the international measurement system. NIST accomplishments in this area—ranging from measurement reference materials, to electron counters, to single-molecule measurements—contribute to nearly every nanotechnology-related pursuit.

Nanomaterials—Engineering matter on the nanoscale makes it possible to tailor-make materials optimized for specific uses—from new insulators for integrated circuits, to superior stealth coatings for military aircraft, to innovative biocompatible materials for implanted biomedical devices. To study these new materials, NIST is developing new instruments to probe their properties and three-dimensional atomic structures, and devising high-speed screening methods so that future "nanoengineers" can quickly evaluate their creations.

Fundamental nanoscale phenomena and processes—NIST research contributes fundamental knowledge and theoretical frameworks to aid our understanding of nanoscale structures, processes, and mechanisms, pointing the way to new opportunities and future applications of nanotechnology.

Nanomanufacturing—Pursued from both the top-down and the bottom-up, NIST research is furthering the development of reliable, cost-effective methods for processing nanomaterials and for producing, assembling, and integrating commercially viable nanoscale materials, devices, and systems.



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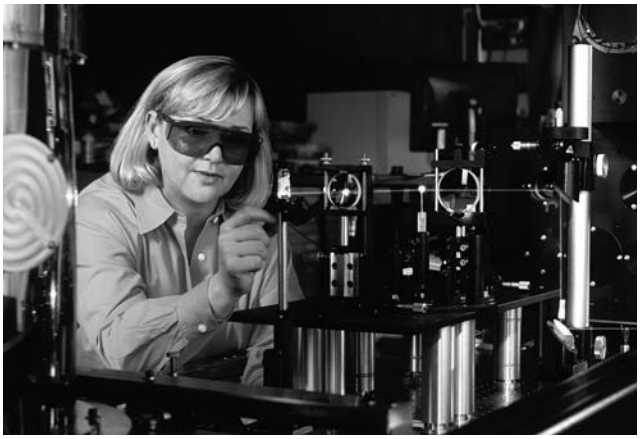
NIST guest researcher and Johns Hopkins physics professor Collin Broholm checks the alignment of the 20 neutron energy analyzers that are part of the Multi-Axis Crystal Spectrometer (MACS), a new instrument at the NIST Center for Neutron Research. MACS is specially designed to investigate the unique nanoscale properties of materials.

Nanoscale Devices and Systems—This research area exemplifies how nanotechnology is a two-way street at NIST. The agency is developing measurement tools and methods necessary to improve and further miniaturize electronic, magnetic, and other types of devices and systems—or to develop entirely new types of next-generation technologies. NIST also leverages advances in nanotechnology to improve its measurement capabilities and related services in a wide range of technical areas that underpin research and commerce.

Environment, Health, and Safety (EHS)—NIST research and services are essential to achieving the important objective of minimizing the potential risks of nanotechnology while maximizing its intended benefits. Under the NNI



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NIST physicist Angela Hight Walker examines some of the world's highest quality single-walled carbon nanotubes using NIST's unique Raman spectroscopy measurement facility. By developing improved characterization methods and measurement protocols, NIST is helping industry and academic researchers determine which type of carbon nanotube is best suited for their high-tech applications such as electronics and nanomedicine.

Strategy for Nanotechnology-Related Environmental, Health, and Safety Research, NIST is the coordinating federal agency for work on the instrumentation, metrology, and analytical methods necessary for identifying and preventing risks posed by engineered nanomaterials. Work in this area is cross-cutting, yielding results useful to progress in the other four research categories that make up the EHS strategy.

Major Research Facilities and Instrumentation Acquisition—NIST funds and manages facilities and a large assortment of world-class instruments, including custom-made equipment designed to tackle key measurement challenges. This collection of advanced tools is a valuable hub in the nation's evolving science and engineering infrastructure for nanotechnology research and development. The centerpiece in this collection is a new user facility:

CNST's Nanofab Facility—Opened in May 2007, this nanofabrication and nanomeasurement facility is staffed and equipped to help researchers and organizations solve nanoscale measurement problems that are hindering the commercial development of nanotechnology. The facility includes a 19,000-square-foot cleanroom (with 8,000 square feet at class 100) featuring more than 30 state-of-the-art tools. The Nanofab is open to all on a fee-based, shared-use basis, providing users with equipment, expert training, and a high level of flexibility.

For more information on NIST's nanotechnology research, facilities, and services, visit www.nist.gov/public_affairs/nanotech.htm or contact inquiries@nist.gov, (301) 975-NIST (6478).